BBC RD 1989/1

Research
Department
Report

PROTECTION OF VHF INTERNATIONAL DISTRESS FREQUENCIES FROM HARMONIC RADIATION DUE TO DIGITAL TELEVISION EQUIPMENT

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Summary

Digital television picture processing equipment uses a luminance sampling frequency of 13.5 MHz which can give rise to harmonics at 121.5 and 243 MHz. If such equipment becomes sufficiently widespread as will probably be the case with MAC/packet receivers, it is possible that the cumulative radiation could become significantly high. Since these frequencies are used by the international distress services there is a potential for interference if this unwanted radiation is not controlled at the point of manufacture.

Over the last two years this problem has been studied in detail by the BBC in conjunction with the EBU. The conclusion is that the distress services will be protected provided that digital television picture processing equipment meets existing Electromagnetic Compatibility (EMC) standards for information technology equipment. In the case of domestic television this should not present a problem, but for studio equipment, because of its size and complexity, EMC compliance may not be so easy.

Issued under the Authority of

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Research Department, Engineering Division,
BRITISH BROADCASTING CORPORATION

(RA-242)

1989

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1. INTRODUCTION

The BBC in conjunction with the EBU has recently completed an investigation into the potentially interfering aspects of harmonic radiation from digital television equipment to international distress services. The EBU group (Sub-Group R/DIS) consisted of members of broadcast organisations, research establishments, PTTs and industry, each member making significant contributions to the study.

The investigation basically comprised three parts:

a) Development of a mathematical model which estimates the cumulative signal due to multiple co-frequency sources.

b) Examination of the systems used by the distress services and determination of interference limits to avoid impairment of service.

c) Use of a) and b) to determine the resulting safety margins for various situations assuming the application of a current Electromagnetic Compatibility (EMC) standard. (If the resulting safety margins are inadequate, to determine by how much the EMC limit must be reduced.)

BBC Research Department made a number of significant contributions to the EBU study, and this Report, whilst summarising the results of the overall investigation, describes in detail the contributions made to it by the BBC.

2. OUTLINE OF THE PROBLEM

Clock frequencies used in digital studio equipment conforming to CCIR Rec. 601[1] and receivers complying with MAC/packet family specifications[2] generate harmonics of their clocking frequencies at exactly 121.5 MHz and 243 MHz. Unfortunately these are internationally agreed distress frequencies and are used by aircraft and satellites for search and rescue purposes. Care must therefore be taken to ensure that harmonic radiation cannot impair the operation of these services.

The main area of concern is where these frequencies are used by Emergency Location Transmitters (ELTs) and Emergency Position Indicating Radio Beacons (EPIRBs). Both devices are intended to be received either by aircraft or helicopter or by a SARSAT/COSPAS polar orbiting satellite. Ground-based receiving stations also monitor these frequencies for transmissions from aircraft in distress and could also suffer from interference due to nearby urban areas.

The BBC together with other European organisations under the auspices of the EBU have made a detailed study which is reported in the following sections.

3. INITIAL APPRAISAL

The first task was to examine the various radiation limits in current use for suitability to this particular problem. BS 6527 or its international equivalent CISPR 22, which is applicable to Information Technology Equipment (see Appendix 1) seemed the most logical choice although it was recognized that, because of the potentially high number of co-frequency sources, this limit might not be sufficiently stringent.

A hypothetical situation was then envisaged whereby an aircraft, flying over an urban area, attempts to receive signals from a distant ELT.

It was assumed that the town covered an area 10 km × 10 km and contained 100,000 working MAC/packet receivers and that the harmonic radiation from each receiver at 121.5 MHz was the maximum allowed according to BS 6527, Class B, i.e. 30 dB(μV/m) at a distance of 10 metres. Also the building attenuation associated with each receiver was taken to be 20 dB.

The combined radiation due to the MAC/packet receivers was calculated using power addition, i.e. the equivalent isotropic power for the town was calculated using the following expression:

$$P_{\text{Town}} = P_i + 10 \times \text{Log N} - A_b \text{ dBm}$$

where P_i = the equivalent isotropic power for each source (dBm)

N = the number of potentially interfering sources

A_b = building attenuation (dB)

The radiated power of the ELT, P_{ELT} was assumed to have a worst case minimum value of 14 dBm and the protection ratio in the aircraft receiver, PR was taken to be 17 dB, the value used for voice communication. The aircraft must be a certain minimum distance from the town to achieve this protection ratio and this distance was calculated using the relationship:

$$20 \text{ Log } d_{\text{Town}} = P_{\text{Town}} - P_{\text{ELT}} + \text{PR} + 20 \text{ Log } d_{\text{ELT}}$$

The result is a near circular zone over the town within which the aircraft receiver may respond to interference. The size of this zone depends on the distance to the ELT; the greater the distance, the larger the zone. Fig. 1 shows the zone size for distances of 30, 50 and 100 km from the ELT, all other factors being the same.

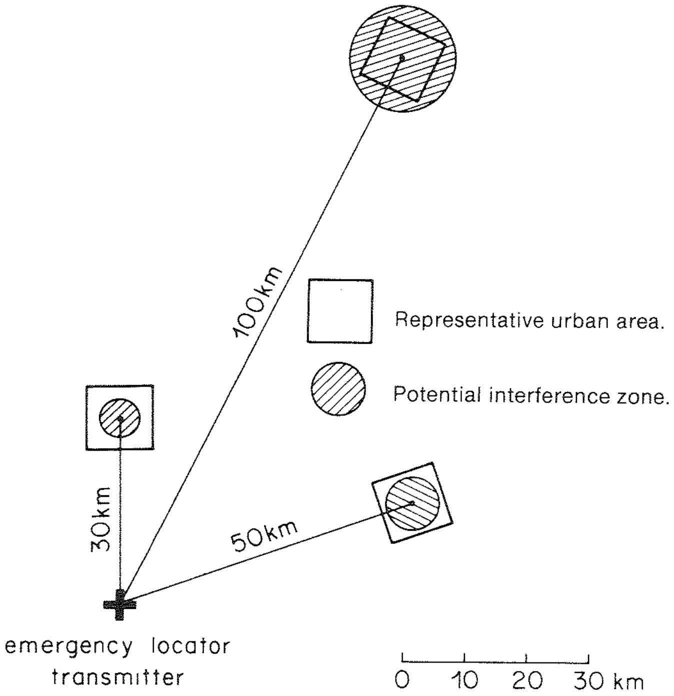
100km
Representative urban area.
Potential interference zone.
30km
50km
emergency locator transmitter
0 10 20 30 km

Fig. 1 - Limited assessment of potential interference zones.

The main point to be drawn from this was that, whilst there appeared to be a potential for interference to the reception of distress signals, the spatial volume where this could occur seemed to be confined fairly closely to the relevant urban area and in reality would not impair the operation of the search and rescue services.

The satellite-based distress service, which is based on a series of polar low-orbiting satellites of the SARSAT/COSPAS type, was briefly considered. Since much larger path lengths of at least 850 km are involved it was thought that this service would be even less susceptible to interference than the aircraft-based system. Later, when performance details became available, this assumption was found to be untrue. (See Section 4.2.)

It was realised at the time that this was a first appraisal of the problem and that other factors may be involved. There were uncertainties about the value assumed for building attenuation (was 20 dB too high or too low?) or whether power addition was a valid method to use for summing the signals from many co-frequency sources. Information on the satellite system was also lacking. However the work did serve to indicate that the radiation limits contained in CISPR 22, if applied to digital television equipment, might be sufficient to prevent interference to the distress services.

4. DETAILED STUDY

During the following months the various problems were studied in detail by members of the EBU Sub-Group and their findings will now be discussed. For a fuller explanation of the calculation methods and parameters used the reader is referred to the final report of Sub-Group R/DIS[4].

4.1 Calculation of signal at the distress receiver input

It was shown through theoretical analysis and computer simulation that the combined signal at the receiver due to many co-frequency sources would follow a Rayleigh distribution for which a corresponding r.m.s. voltage could be calculated. The effect of building attenuation was also assessed statistically by assuming a log-normal distribution with a mean value of 22 dB and a standard deviation of 12.5 dB* instead of using a fixed value of 20 dB.

Equipment manufacturers who have to meet a particular emission limit invariably make their product to a tighter specification to allow for production spread. This safety margin results in a mean emission level which is lower than the specified limit and this fact was accounted for in the calculation. A mean of 6 dB has been used together with a standard deviation of 2 dB.

4.2 The satellite-based distress service

As stated in Section 3 it was originally thought that the satellite service would be least affected due to the large path loss involved. However examination of the performance parameters[5] by the BBC revealed that the satellite transponders employ advanced signal processing techniques which enable extremely low level signals to be received. In effect the system uses a very narrow bandwidth (50 Hz) which is swept across the channel at regular intervals. It is therefore extremely sensitive, capable of a received signal threshold of -40 dBμV and, at first sight, is quite capable of detecting the radiation from, for example, a large land mass containing millions of MAC/packet DBS receivers.

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* These values were obtained by Mir and White[6] at a frequency of 150 MHz.

Further study showed that the system works by measuring the Doppler shift of an incoming ELT/EPIRB signal to derive an approximate location reference for use by the search and rescue services. It then became apparent that this Doppler shift in conjunction with the narrow bandwidth would mean that, at any given time, the system would only respond to sources on the earth's surface contained within the boundaries of a narrow strip, normal to the satellite track. At any moment in time this effective area greatly reduces the number of sources that can be received by the satellite. A detailed analysis of this Doppler effect is given in Appendix 2.

4.3 The final equation

The final equation derived by the EBU Sub-Group for calculating the voltage at the terminals of a distress receiver (aircraft or satellite) due to harmonic radiation from multiple co-frequency sources (MAC/packet decoders or digital television studio equipment) is given by:

$$V_{\mathrm{rms}} = C_A\, E_L\, K_S\, d_L\, \sqrt{K_D\, \mathrm{N}}\; 10\; \frac{-(\mathrm{m_B}-\mathrm{m_M})}{20} \cdot$$

$$\cdot \exp\left\{(\sigma_B^2 + \sigma_m^2)\left(\frac{ln\ 10}{20}\right)^2\right\} \cdot$$

$$\cdot \sqrt{E\left[\left(\frac{a(d_i)}{d_i}\right)^2\right]}$$

where

V_{rms} = r.m.s. voltage at receiver input (μV)

C_A = receiver antenna factor

E_L = specified field strength limit (μV/m) at a distance d_L (m) for a single potentially interfering source (e.g. CISPR 22 limit)

K_S = source radiation pattern factor

K_D = reduction factor due to Doppler effect

N = total number of acting interfering sources

m_B = mean value of building effect (dB)

σ_B = standard deviation of building effect (dB)

m_M = mean value of manufacturers safety margin (dB)

σ_M = standard deviation of manufacturers safety margin (dB)

d_i = distance of source i to receive antenna (m)

$a(d_i)$ = antenna gain in direction of source i at distance d_i

$E[(a(d_i)/d_i)^2]$ = Expectation value of the square of the antenna gain/distance factor $a(d_i)/d_i$

4.4 Derivation of potential interference limits

Having developed a method which estimates the cumulative signal due to multiple sources it was then neccessary to establish safe limits for such a signal to prevent interference to the distress services.

4.4.1 Aircraft-based distress service

In the initial appraisal (Section 3) the level of potential interference was assessed on the basis of a 17 dB protection ratio. No account was taken of absolute receiver sensitivity. However the reception of ELT signals may require that the receiver be used in its most sensitive mode (squelch de-activated). In fact minimum operational performance standards[7] for ELTs are based on an aircraft receiver sensitivity of -120 dBm. Therefore -13 dBμV has been used as the interference limit for the case of an aircraft flying over a nominally rural area.

However, for an aircraft flying over urban areas an allowance has been made for the fact that existing man-made noise already degrades receiver performance. From measurements made of antenna noise temperatures[4] it has been found that typical noise levels in a 25 kHz bandwidth at a height of 10 km are -8 dBμV for a population of 1 million and 1 dBμV for a population of 8 million. Hence for an aircraft flying over a typical 'city' a limiting value of -8 dBμV is used, but for larger urban areas such as London the limit is raised to 1 dBμV.

4.4.2 Satellite-based distress service

In the case of the satellite system the SARSAT/COSPAS performance specification[5] quotes the minimum detectable signal in terms of an e.i.r.p. of -16 dBm which corresponds to a receiver input voltage of -40 dBμV at the operational height of 850 km. This value is used as the interference limit.

Table 1

Case	Height h (km)	Radius R (km)	Population	Number of active sources N (dBμV)	Calculated rms voltage at antenna terminals (dBμV)	Interference limit (dB)	Margin
a) Aircraft/city	10	15	1×10^6	8.3×10^4	−8 (−7)	−8	0 (−1)
b) Aircraft/London	10	28	8×10^6	6.5×10^5	−4 (−3)	1	5 (4)
c) Aircraft/rural	0.78	115	5×10^6	4×10^5	−18 (−17)	−13	5 (4)
d) Aircraft/studio	10	0.1	—	1×10^3	−22 (−21)	−8	14 (13)
e) Aircraft/O.B.	10	0.01	—	10	−43 (41)	−13	29 (28)
f) Satellite/city	850	15	1×10^6	8.3×10^4	−44 (−43)	−40	4 (3)
g) Satellite/London	850	28	8×10^6	6.5×10^5	−38 (−37)	−40	−2 (−3)
h) Satellite/Global	850	3651	6×10^8	5×10^7	−47 (−46)	−40	7 (6)
i) Satellite/studio	850	0.1	—	1×10^3	−64 (−63)	−40	24 (23)
j) Satellite/O.B.	850	0.01	—	10	−81 (−80)	−40	41 (40)
k) Ground station/city	0.01	15	1.2×10^6	8.3×10^4	−7 (−6)	−8	−1 (−2)
l) Ground station/O.B.	0.4	0.01	—	10	−14 (−13)	−13	1 (0)

4.4.3 Ground stations

The case of potential interference to a ground monitoring station by harmonic radiation from an adjacent urban area is covered by assuming a basic aircraft receiver sensitivity with an allowance for existing man-made noise. A limiting value of −8 dBμV is used.

4.5 The analysis

Using the equation described in Section 4.3 it was then possible to calculate the cumulative signal at the receiver for various likely situations. In all, 12 cases were studied. These are listed in Table 1 where the calculated r.m.s voltage at the receiver terminals is compared with the potential interference limit at 121.5 MHz. The figures in brackets refer to 243 MHz.

In all cases the single source radiation limit is that recommended in CISPR 22, Class B, i.e. the field strength at a distance of 10 metres is 30 dB (μV/m) at 121.5 MHz and 37 dB (μV/m) at 243 MHz.

It can be seen from the last column, where a positive margin indicates that the interference limit has not been exceeded, that the majority of situations will be adequately protected against interference by the adoption of the CISPR 22, Class B radiation limit. In the case of studio equipment, the margin is sufficiently high to enable the more relaxed (10 dB higher) Class A limit to be used.

Where negative margins do occur (over cities) they are only of the order of a few decibels and do not indicate a serious problem. Existing man-made noise is already apparent in these situations and any additional contribution from digital television equipment is not likely to be significant.

The enhanced sensitivity of the satellite system appears to be adequately protected although, as the density of the MAC/packet system reaches saturation, radiation from large cities may just become apparent. However it should be noted that this system is already impaired by existing man-made noise and by the fact that the ELT/EPIRBs do not have sufficient frequency stability for accurate position fixing (since they were never originally designed for such a system). As a result, a new satellite system is being introduced which overcomes these disadvantages. It uses a frequency of 406 MHz (which is not harmonically related to 13.5 MHz) and requires specially designed ELT/EPIRBs. Eventually it is likely to supersede the existing system.

5. THE MEASUREMENT OF RADIATION FROM DIGITAL PICTURE PROCESSING EQUIPMENT

Whilst MAC/packet receivers are not yet commercially available, digital picture processing equipment is becoming increasingly apparent in studio centres. However much of it is still in prototype form and may not be truly representative in terms of emission levels. Nevertheless any radiation measurements made at this stage will serve to indicate how feasible or not the implementation of the CISPR 22 limit might be. With this in mind measurements were made by the BBC of radiation at 121.5 and 243 MHz from various items of available equipment. These are summarised as follows:

5.1 Domestic receiving equipment

At the time, no MAC/packet decoders existed which were of the type to be used in mass-produced DBS receivers. Therefore to simulate the harmonic generating properties of such a decoder a CMOS clock circuit, running at 13.5 MHz, was constructed. This had a capacitive load to simulate a high number of logic gates. Field strength measurements showed that, even with no screening, harmonic radiation at 121.5 MHz was at least 16 dB below the CISPR 22, Class B limit. It was concluded that receiver manufacturers should have no problem implementing this limit.

5.2 Studio equipment

Measurements made on various pieces of prototype equipment used for producing computer-generated television graphics showed that the CISPR 22, Class B limit was exceeded by about 16 dB. Details of this work are contained in Appendix 3. In general, no significant EMC measures had been used in the construction of this equipment. Moreover it was found that the application of simple screening techniques and the bonding of side panels had negligible effect on the overall level. This led to the conclusion that the control of spurious radiation must be considered at the design stage if it is to be effective. The main problem is that such equipment is considerably larger and more complex than say a MAC/packet decoder and is therefore more difficult to screen effectively.

However the analysis (Section 4.5) has shown that it is possible to adopt the Class A limit for studio equipment. This is permissible since the overall number of potentially interfering sources and the area which they occupy are much smaller than say a town containing many thousands of MAC/packet DBS receivers. Also the surrounding building structure is more likely to provide better screening than a typical domestic dwelling. Nevertheless, specific attention to avoidance of spurious electromagnetic radiation will still have to be taken at the design stage with future digital television studio equipments to ensure that they meet the CISPR 22 Class A limit.

6. CONCLUSIONS

Studies carried out by the BBC in conjunction with EBU Sub-Group R/DIS have shown that the existing EMC limits for Information Technology Equipment (CISPR 22) will, if applied to digital television picture processing equipment, provide sufficient protection to international distress services using 121.5 and 243 MHz.

In particular, domestic equipment such as MAC/packet DBS receivers should be manufactured to comply with the emission limit given in CISPR 22, Class B and digital television studio equipment should similarly comply with the emission limit given in CISPR 22, Class A.

Whereas compliance with the Class B limit is not expected to be a problem for domestic television receivers, a considerable amount of work is needed to enable all digital studio equipment to meet the Class A limit.

7. ACKNOWLEDGEMENTS

The analysis of the Doppler effect was carried out by J. Tyler and the measurement work by J.H. Moore.

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APPENDIX 1

Electromagnetic Radiation Limits

The CISPR 22 limit[3], which applies to Information Technology Equipment, recommends the maximum level of radiated spurious emission from a single source and is similar to BS 6527. It is divided into two classes, A and B.

Class B refers to typical domestic establishments. The limiting field strength at a distance of 10 metres is 30 dB(μV/m) at 121.5 MHz and 37 dB(μV/m) at 243 MHz.

Class A refers to typical commercial establishments. The field strength limit is the same as Class B but the distance at which it is measured is increased to 30 metres so that there is effectively a 10 dB relaxation in emission requirements.

The European Norm (CENELEC EN55 022) has evolved from CISPR 22 and is likely to become mandatory by 1989.

APPENDIX 2

The Effect of Doppler Shift on Satellite Reception of Harmonic Radiation from DBS MAC/packet Receivers

The SARSAT system locates emergency distress beacons on the earth's surface by measuring the Doppler shift of the received signal. The amount of frequency shift will depend on the relative position of the beacon with respect to the satellite.

For example, the moment that the satellite is exactly above the beacon, Doppler shift will be zero, whereas the signal from a beacon on the horizon and on the satellite's track will experience maximum shift. Beacons on either side of track will result in proportionately less Doppler shift at the satellite.

In the same way, signals from MAC/packet deocders will also be Doppler shifted. The resolution bandwidth of the SARSAT system is only 50 Hz at 121.5 MHz (100 Hz at 243 MHz) so that those sources which have been shifted by more than this amount effectively will not be received. This results in a reduction in the effective area (and hence the number of sources) to what is essentially a narrow strip as shown in Fig. A2.1. This also has a secondary effect in that the source distribution is changed, which affects the antenna/distance factor.

This Appendix shows how these effects are evaluated for use in calculating the cumulative received voltage. The worst-case potential r.f.i. problem is assumed, i.e. when the satellite (at height h) is directly above a town (with radius R). Because the resulting strip is relatively narrow, the effects of earth curvature can be ignored in the direction of satellite travel and cylindrical rather than spherical co-ordinates can be used, thereby simplifying the ensuing calculation.

A2.1 Reduction in the effective number of sources

In Fig. A2.1 the total area, containing N sources, is that part of the earth's surface which can be seen from the satellite and is given by

$$A_O = 2\pi R_t^2 (1 - \cos(R/R_t))$$

Where R is the radius of the area and R_t the radius of the earth.

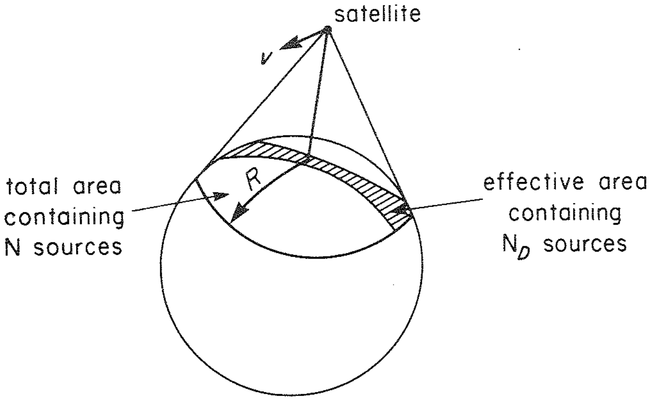
satellite
v
R
total area containing N sources
effective area containing N_D sources

Fig. A2.1 - Area reduction due to Doppler effect.

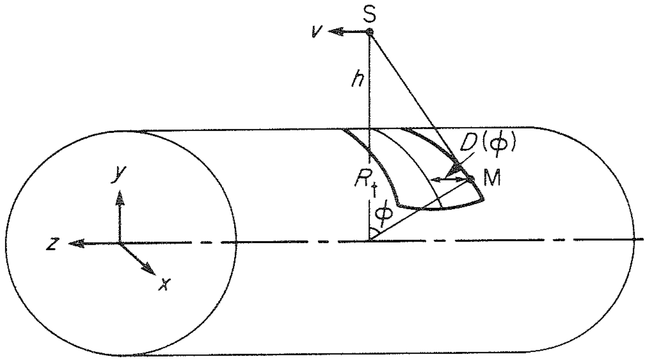

Fig. A2.2 - Analysis using cylindrical co-ordinates.

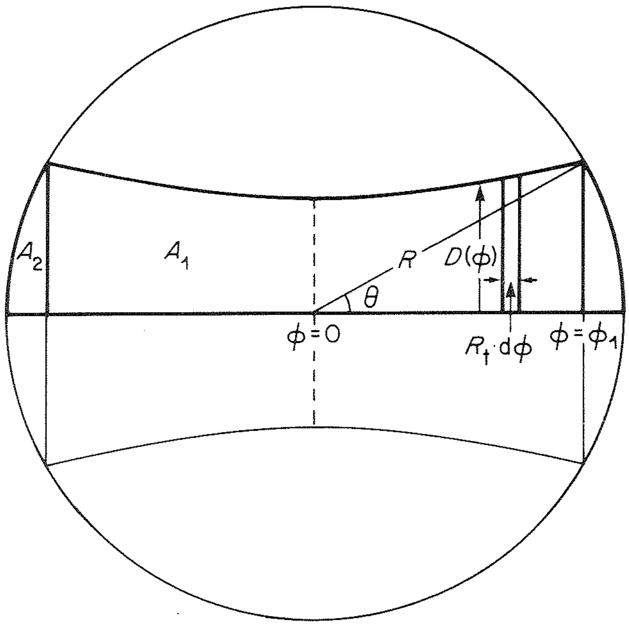

Fig. A2.3 - Plan view of the effective area.

The effective area is that of the strip, which is more readily determined using cylindrical co-ordinates as in Fig. A2.2. This effective area, containing N_D sources, is shown more clearly in Fig. A2.3 and is given by $4\,(A_1 + A_2)$.

Hence the effective reduction in the number of sources is given by

$$K_D = 4\,(A_1 + A_2)/A_0 \qquad \text{(A2.1)}$$

The effective sub-areas A_1 and A_2 are determined as follows:

Area A_1

In Fig. A2.2, the satellite position is given by $S = (R_t + h)\ 0,\ 0)$ and a point on the earth's surface by $M = R_t, \phi, D(\phi)$

As shown in Fig. A2.3 the elemental area is given by $D(\phi)\ .\ R_t\ .\ d\phi$ where $D(\phi)$ is the half-width of the strip. Hence A_1 can be found from the integral:

$$A_1 = \int_0^{\phi_1} D\,(\phi)\, R_t\, d\,\phi \qquad \text{(A2.2)}$$

Where ϕ_1 defines the point of intersection of $D(\phi)$ and radius R,

$$\phi_1 = \frac{R^2 - D^2\,(\phi_1)}{R_t}$$

$D(\phi)$ is calculated as follows:

The relative velocity between the satellite S and point M is given by

$$v_{\mathrm{DS}} = \frac{\overline{\mathrm{MS}}}{|\,\mathrm{MS}\,|} \cdot \overline{v} \qquad \text{(A2.3)}$$

Where $\overline{v} = (0, 0, v)$

The edge of the effective area is determined by the Doppler shift frequency limit f (which, because of the 50 Hz system bandwidth, is ±25 Hz). This is related to the relative velocity between source and satellite by

$$v_{\mathrm{DS}} = (f_{\mathrm{DS}} / f_0) \cdot c$$

Where f_0 = source frequency
c = velocity of light

The source to satellite distance d_i is given by

$$d_i^2 = R_t^2 + (R_t + h)^2 + D^2(\phi) - 2R_t (R_t + h) \cos \phi \qquad \text{(A2.4)}$$

Hence from Equation (A2.3)

$$v_{\mathrm{DS}} = \frac{-D(\phi) \cdot v}{\sqrt{R_t^2 + (R_t + h)^2 + D^2(\phi) - 2\, R_t (R_t + h) \cos \phi}} \qquad \text{(A2.5)}$$

Putting $K_v = v_{\mathrm{DS}}/v$ and rearranging Equation (A2.5) for $D(\phi)$ yields

$$D(\phi) = K_v \sqrt{\frac{R_t^2 + (R_t + h)^2 - 2\, R_t (R_t + h)^2 \cos \phi}{1 - K_v^2}} \qquad \text{(A2.6)}$$

This is the half-width of the Doppler strip. Table A2.1 indicates how this varies with area radius, R. It can be seen that the strip becomes wider as R increases.

Table A2.1

R(km)	Doppler strip-width (km)
10	7.0
100	7.1
1000	11.2

The integral given in Equation (A2.2), which contains $D(\phi)$ can now be solved. This is most easily done numerically.

Area A_2

As shown in Fig. A2.3 this area is the difference between a segment, radius R and included angle θ and the right-angled triangle with the same angle θ and hypotenuse R.

Therefore

$$A_2 = \frac{1}{2} \left[R^2 \sin^{-1} \left(\frac{D(\phi)}{R} \right) - D(\phi) \sqrt{R^2 - D^2(\phi)} \right] \qquad \text{(A2.7)}$$

By using Equations (A2.1), (A2.2), (A2.6) and (A2.7) we can determine, albeit numerically, the reduction in the effective number of sources to give the ratio $K_D = N_D/N$.

A2.2 Change in shape of source area

The antenna factor $a(d_i)$ and the far field propagation law $1/d_i$ are variables which are dependent on the source distribution. The expected mean square value of the variables is used in the statistical model of the system. Because of the Doppler criteria we can no-longer consider the source distribution to be over a circular area and must modify the calculation to take account of the strip shown in Fig. A2.3.

The probability density $p(\phi)$ is given by

$$p(\phi) = \frac{D(\phi)\,R_t}{A_1 + A_2}\,, \qquad 0 < \phi < \phi_1 \tag{A2.8}$$

and
$$p(\phi) = \frac{R_t\sqrt{R_t^2 - (R_t \cdot \phi)^2}}{A_1 + A_2}\,, \qquad \phi_1 < \phi < R/R_t \tag{A2.9}$$

Since $D(\phi) << h$, the source to satellite distance given by Equation (A2.4) reduces to

$$d_t^2 = R_t^2 + (R_t + h)^2 - 2\,R_t\,(R_t + h)\cos\phi \tag{A2.10}$$

The antenna pattern is assumed to have a cosine law

$$a(d_i) = h/d_i$$

hence the antenna/distance factor is given by

$$E\left[\left(\frac{a\,(d_i)}{d_i}\right)^2\right] = \frac{h^2\,R_t}{A_1 + A_2}\left(\int_0^{\phi_1}\frac{D\,(\phi)\,\mathrm{d}\phi}{d^4} + \int_{\phi_1}^{R/R_t}\frac{\sqrt{R^2 - (R_t\,\phi\,)^2}}{d^4}\,\mathrm{d}\phi\right)$$

which, like Equation (A2.2), is best solved numerically.

These Doppler effects are illustrated in Fig. A2.4.

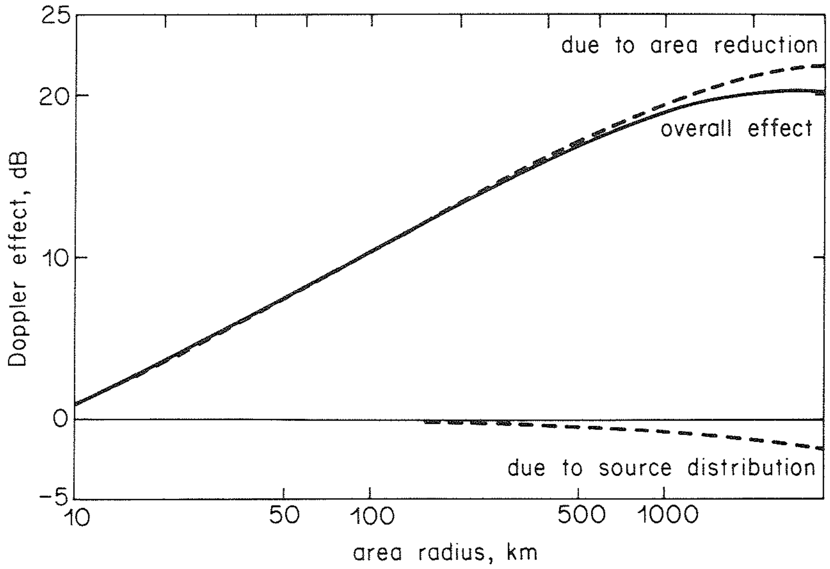

Fig. A2.4 - Variation of Doppler effect with area radius.

APPENDIX 3

Measurement of Harmonic Radiation from Digital Picture Processing Equipment

A3.1 Introduction

To ascertain the severity of the potential interference problem, field strength measurements have been made on experimental digital picture processing equipment in which no special EMC precautions have been taken.

Appendix 4 gives details of the measuring system and site at BBC Research Department. The measurements reported were restricted to 121.5 MHz.

A3.2 Details of the experimental digital picture processing equipment

The experimental equipment was constructed in a chassis system used within the BBC known as Binary Metric Modular (BMM). Fig. A3.1 shows a typical BMM rack. This is based on a panel or frame consisting primarily of two aluminium side-plates separated by four long aluminium extruded bars. Plug-in chassis as well as unsupported printed wiring boards can be accommodated in the frame on polycarbonate runners. The actual width of these chassis or wiring boards is based on a binary metric spacing, so as to ensure various chassis widths can fill a frame width without leaving gaps on the front elevation. This form of construction is similar to several commonly used in commercial equipment and is therefore likely to be broadly representative in terms of EMC performance.

No special provision for RF screening had been made, so for these measurements additional screening was fitted to the modular sub-units fixed into the two main racks of the equipment.

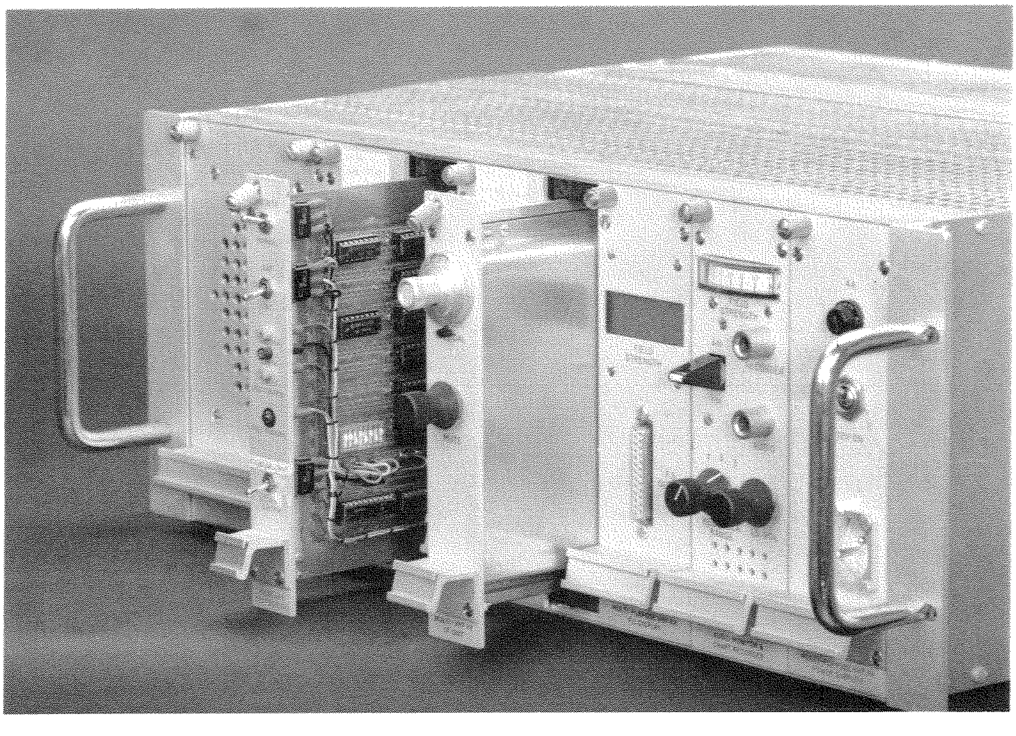

Fig. A3.1 - Binary Metric Modular (BMM) Rack System.

This screening took the form of a metal back panel which enclosed the rear of the two vertically stacked main racks. Two holes about eight centimetres diameter were cut into this panel, so as to allow egress for cables and to provide ventilation. To ensure good electrical contact between the main racks and the screening panel, a phosphor bronze gasket was fixed with many small screws to the cleaned metal surface of the panel. The screening panel was bolted to the main chassis with several screws ensuring a low RF impedance to earth. Similarly, to ensure a low RF impedance to earth for the front panels of the BMM sub-units, the polycarbonate moulded chassis guides were undercut so that, when the sub-units were inserted, the rear of the front panel came into metallic contact with the lower front horizontal extrusion of the panel frame assembly. At this point of contact, the anodising of the front panel was removed.

BBC safety regulations require that earth continuity exists between the front panel and the panel frame assembly, either via screws holding the front panel to the chassis runner or via an earthing track of the printed wiring board affixed to the chassis runner. This arrangement provides safety earth continuity, but presents a relatively high impedance earth return for any circulating RF currents, therefore the anodising was removed from the corresponding surface of the BMM panel frame assembly to create a low RF impedance to earth.

A3.3 Results

The results given in Table A3.1 have been obtained using the procedures outlined in CISPR 22 and are quoted in terms of the maximum field strength measured at a distance of 10 m from the equipment under test.

Table A3.1

Measurement of spurious emissions at 121.5 MHz from experimental digital picture processing equipment

Test	Equipment details	Worst case field strength at 10 m (dBμV/m)	Measurement uncertainty (dB)	Amount by which CISPR 22 is exceeded (dB)
1	Picture processing equipment without additional back-panel	46	3	16
2	Picture processing equipment with additional back-panel	49	2	19
3	As in 2, but with mains supply lead wrapped around ferrite toroid	43	3	13
4	As in 3, but with wire mesh cage over whole apparatus	34	4	4

With no additional screening, the picture processing equipment exceeds the CISPR 22 specification (Class B) by about 16 dB (Table A3.1, Test 1). The addition of a 'screening' back panel (Table A3.1, Test 2) actually increased the maximum emission level, the most likely explanation being that the spurious signals leaking from the equipment have become more directional, and thereby enhancing the strength of the radiated interference in certain directions.

As mentioned previously, the screening back panel had, by necessity, holes cut into it to allow egress of various cables and to provide ventilation. The cables consist of co-axial, multiway ribbon, low voltage d.c. and mains supply.

The mains supply cables, where they enter a rack, usually have power line RFI suppression filters to protect the equipment from mains-borne interference. Naturally these filters also prevent any interference generated within the apparatus passing beyond the confines of the filter. However the efficacy of the filters at frequencies above 30 MHz is sometimes uncertain, and therefore the technique of winding the mains supply lead around a ferrite toroid can reduce the transmission of spurious signals along the mains lead. With reference to the results shown in Table A3.1, Test 3, the technique of winding the mains supply cable around a ferrite toroid has reduced the emissions by 6 dB. Co-axial and multiway ribbon cable interconnections usually have no such filters and therefore it is quite likely that signals are radiated, either by direct leakage from the energised conductor or from the screening braid of the co-axial cables and the conductors of ribbon cables, including their earth return.

Although filters can be used on signal cables, the parameters of these filters will require very careful selection so as not to modify the required operational characteristics of the electronic circuitry. As with all measures to improve electromagnetic compatibility, the filters will be most effective if part of the equipment design, and it has become clear that piecemeal attempts to reduce spurious radiation are unlikely to be consistent nor sufficiently effective.

The only fairly successful experimental arrangement was to totally screen the entire apparatus and its associated connecting leads, as in Test 4. Even so, the CISPR specification was still exceeded, but only by about 4 dB.

The results have also shown that screening can make the picture processing equipment rack a more directional radiator, thereby enhancing the strength of the radiated interference in certain directions. To reduce the possibility of this effect remaining unnoticed, field strength measurements were made on each of the four faces of the equipment rack. The field strength recorded in Table A3.1 is the maximum of HP and VP for the antenna elevated in the range 1½ to 4 m. Care was taken to minimise the effects of standing waves caused by ground reflection. The uncertainty values quoted are an estimate of the variations in field strength due to experimental arrangements.

APPENDIX 4

Details of Measuring Equipment and Site

The test equipment is shown in Fig. A4.1 which also shows the remotely controlled turntable with experimental digital picture processing apparatus mounted upon it. A plan view of the test site is shown in Fig. A4.2. The measurement antenna is an adjustable dipole, mounted on a wooden mast, capable of elevation up to 4 metres. The polarization can be horizontal or vertical as required.

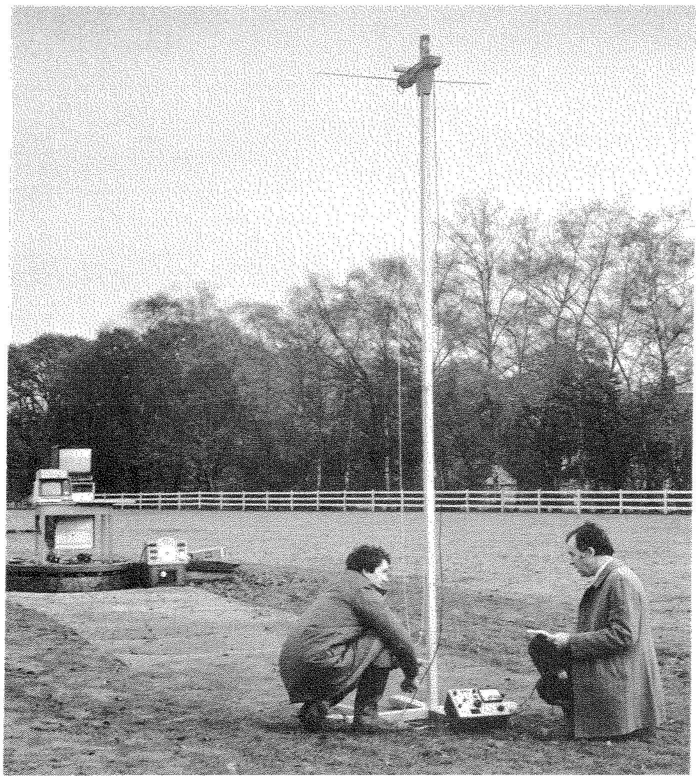

Fig. A4.1 - Radio frequency measurement site for equipment under test at Research Department.

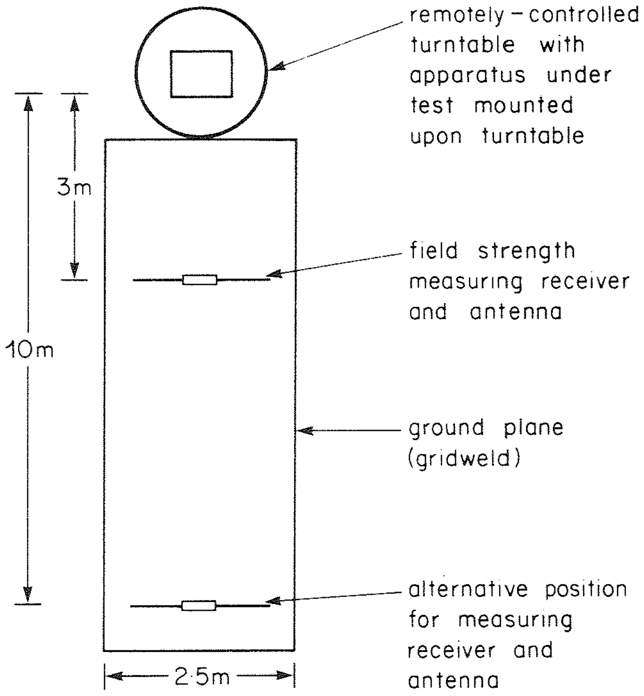
remotely - controlled turntable with apparatus under test mounted upon turntable
3m
field strength measuring receiver and antenna
10m
ground plane (gridweld)
alternative position for measuring receiver and antenna
2·5m

Fig. A4.2 - Plan of test site.

Printed by BBC RESEARCH DEPARTMENT, Kingswood Warren, Tadworth, Surrey, KT20 6NP